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Partulids on Tahiti: Differential persistence of a minority of endemic taxa among relict populations*

Trevor Coote

BP 2407, Papeete 98713, Tahiti, French Polynesia, partula2003@yahoo.co.uk

Abstract: The extinction of many species of endemic land snails in French Polynesia because of the introduction of the carnivorous snail *Euglandina rosea* is a salutary lesson in hasty biological control undertaken without adequate scientific field trials. Fewer than 20 of the original 70+ nominal species of the family Partulidae in French Polynesia survive. In 2004 surveys were carried out in nearly 70 of the valleys of Tahiti. All of the populations found were of *Partula hyalina*, the closely related *Partula clara*, or *Samoana attenuata*. No individuals of the *Partula otaheitana/Partula affinis* complex were found, yet *P. otaheitana*, together with *Samoana burchi*, still survive in many montane forest areas (over 1000 m altitude), while *P. affinis* persists on the Peninsula of Tahiti. *Partula nodosa*, with a previous distribution of just 7 valleys, has most likely been extirpated in the wild but persists well in captive populations. The species *Partula filosa*, *Partula producta*, and *Partula cytherea* (each previously inhabiting a single valley) are almost certainly extinct, as is *Samoana jackieburchi*.

Key words: Extinctions, Partulidae, biological control, Tahiti, *Euglandina*

The endemic land snails of French Polynesia constitute a significant component of its biodiversity. Their polymorphism in shell color, banding patterns, and coiling has been the focus of classic studies in evolutionary and ecological genetics (Crampton 1916, 1932, Johnson *et al.* 1993). In the past their shells have been collected by local artisans on some islands for making shell jewelry (E. Loève, pers. comm.). The mass extinction of many of the endemic species is an example of a disastrous attempt at biological control without adequate field trials (Clarke *et al.* 1984, Cowie 1992). The giant African snail *Lissachatina fulica* (Bowdich, 1822) was introduced as a food resource in 1967, but spread rapidly and destructively. The solution at the time was wrongly perceived to be the introduction of the carnivorous snail *Euglandina rosea* (Férussac, 1821), which took place on Tahiti in 1974, on Moorea in 1977, and on other islands in the 1980s and 1990s. The predators preferentially attacked the smaller endemic species, notably members of the family Partulidae. Over half of the 120 known species of the family Partulidae were native to French Polynesia. Sadly now most are extinct (Murray *et al.* 1988).

An international captive breeding effort—the only one in the world for an invertebrate family—has continued to maintain a number of species of *Partula* that no longer exist in the wild (Pearce-Kelly *et al.* 1997). An *ad hoc* program of field surveys has been carried out in the Society Islands of French Polynesia over the last few years to establish the exact status of remaining species in their natural habitat and to locate any relict populations that may have survived the ravages of the last 20 years. These surveys have concluded that there is a high probability of virtually all species being extinct on the islands of Bora Bora, Huahine, Raiatea, and Tahaa, and that only Moorea and Tahiti still support remnant populations (Coote and Loève 2003), though there have been recent discoveries of a few partulid individuals on the highest peaks of Huahine and Raiatea (J.-Y. Meyer, pers. comm.). This paper concentrates on a major effort to survey Tahiti Nui, which comprises the bulk of the island of Tahiti—the peninsula of Tahiti Iti has yet to be surveyed.

Tahiti is by far the largest island in French Polynesia. The American biologist, H. E. Crampton (1916) made an extensive study-collection of the genus *Partula* from over 60 valleys (50 on Tahiti Nui and 12 on Tahiti Iti) between 1906 and 1909. The malacologists Y. Kondo and J. B. Burch collected from 33 valleys in 1970 (Anonymous 2004). With the introductions of *Euglandina rosea* to Tahiti in 1974, the first such introduction in French Polynesia, focus changed from pure research to conservation. While undertaking large-scale surveys and emergency collections on Moorea, Murray *et al.* (1988) also undertook smaller surveys of valleys on Tahiti. They searched 11 valleys on visits between 1980 and 1987. Extrapolating from the situation on Moorea, they believed that all species from Tahiti would be extinct within a few years, as many of the valleys were found to be empty already. However, in 1995 a visiting team of biologists from the U.K. and U.S.A., acting on local advice, found thriving populations on Mt. Marau and in the valleys of Te Pari ("the cliffs") on Tahiti Iti. Since that year, a number of isolated popula-

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tions have been discovered at different locations on Tahiti, some of which have since disappeared (Coote *et al.* 1999).

METHODS

Although the nature of the habitat and terrain would have changed almost beyond recognition since his time, the information in Crampton (1916) has still formed the basis of the surveys reported here. Details were refined on the ground, with 1:20,000 scale maps and advice from local people. The majority of the surveys took place between January and September 2004, in the hotter rainy season and the cooler drier season. Each survey of a valley was restricted to a single day. Because of the extreme rarity (and possible non-existence) of partulids in the valleys, simple searches for their presence or absence were carried out in habitats that experience suggested were most amenable to their survival and which were accessible. Using existing forest trails where available and continuing as deep as possible into the valleys, the areas searched were usually patches of around 5 m^2 in size. Where populations were found, all snails seen within the immediate patch were counted inside 20 minutes and descriptive details recorded. Dead shells were collected; those of *Euglandina rosea*, being large and conspicuous, were easily seen.

RESULTS

Seventy-six valleys on Tahiti Nui were identified and 69 of them were surveyed (including 22 on two or more occasions). Access could not be gained to the other 7 valleys. Live populations of partulids were found in 22 valleys (Table 1).

There was no obvious geographical pattern to these finds. They occurred in the north, east, west, and south, in

Table 1. Valleys on Tahiti Nui where partulids survive.

Valley	Administrative commune	Species found	No. of populations	Individuals counted in 20 minute search	Valley type
Fautaua-Faaiti	Papeete	*Partula hyalina*	1	10	Small, dry
Pirae	Arue	*Partula hyalina*	1	*	Large, dry
Ahonu	Mahina	*Partula hyalina*	1	5	Medium, wet
Puhi	Hitia'a O Te Ra, Papenoo	*Partula clara*	1	2	Small, wet
Faarapa	Hitia'a O Te Ra, Papenoo	*Partula hyalina, Partula clara*	Several	5 (hy) 3 (hy) 4 (cl)	Small, wet
Vaipu (Faaromai)	Hitia'a O Te Ra, Tiarei	*Partula hyalina*	1	2	Small, wet
Haapoponi	Hitia'a O Te Ra, Tiarei	*Partula hyalina, Partula clara, Samoana attenuata*	Several	9 (hy) 5 (hy) 3 (cl) 8 (hy) 5 (hy) 4 (cl)	Small, wet
Onohea-Faaiti	Hitia'a O Te Ra, Tiarei	*Partula hyalina, Partula clara*	2	12 (hy) 17 (cl)	Small, wet
Tahaute	Hitia'a O Te Ra, Mahaena	*Partula hyalina*	1	2	Large, wet
Faaiti	Hitia'a O Te Ra Hitia'a	*Partula hyalina*	1	2	Small, wet
Vaiiha (Papeiha)	Hitia'a O Te Ra, Hitia'a	*Partula hyalina, Partula clara*[1]	1	11 (hy) 2 (cl)	Large, wet
Vaitoare	Taiarapu Est, Faaone	*Partula hyalina, Partula clara*	Several	1 (hy) 5 (hy) 1 (cl) 18 (hy) 2 (cl)	Small, wet
Apirimaue*	Teva-I-Uta, Papeari	*Samoana attenuata*	1	—	Large, wet
Vaioo	Teva-I-Uta, Mataiea	*Partula clara*	2	2 6	Small, wet
Faurahi*	Teva-I-Uta, Mataiea	*Partula clara*[1]	1	—	Medium, wet
Taapua	Papara	*Partula clara*	1	1	Medium, wet
Tereia*	Papara	*Samoana attenuata*	1	—	Medium, wet
Tiapa (Hopuetama)	Paea	*Partula clara, Samoana attenuata*	1	14 (hy) 1 (at)	Medium, dry
Papehue	Paea	*Partula clara, Samoana attenuata*	1	1 (cl) 1 (at)	Medium, dry
Maruapo	Punaauia	*Partula clara*	1	4	Small, dry
Matatia	Punaauia	*Partula hyalina*	1	3	Small, dry
Tipaerui	Faa'a	*Samoana attenuata*	1	1	Medium, dry

* Population found by W. Teamotuaitau.

[1] Live *Euglandina rosea* found in valley.

hy = *Partula hyalina;* cl = *Partula clara;* at = *Samoana attenuata.*

valleys big and small, dry and wet (Table 1), although there was a slight tendency for there to be more living snails in the small, wet valleys of the east coast. On the other hand, there was a striking pattern in the persisting species. Apart from a few individuals of the rare *Samoana attenuata* (Pease, 1864), the only snails discovered were of *Partula hyalina* (Broderip, 1832) and the very similar *Partula clara* (Pease, 1864) (Fig. 1). Nearly 76% of the populations of *P. hyalina* and 40 % of *P. clara* were found on one native plant species, the wild red ginger *Etlingera cevuga* (opuhi maohi).

Live individuals of the carnivore *Euglandina rosea* were found in just 10 valleys, including 3 adjacent valleys in Papeari. It does not appear to be an immediate threat to any of the surviving valley populations of partulids on Tahiti Nui. In no valley did I find more than one individual of *E. rosea*.

In addition to the valleys, five mountain tracks on Tahiti Nui and one above Taravao Plateau on Tahiti Iti were surveyed. The conditions for snails are very different above 1000 m elevation compared to the lowland areas of disturbed habitat (Fosberg 1992). In contrast to the valleys, the dominant partulid species surviving in montane forests is *Partula otaheitana* (Bruguière, 1792).

The largest populations still survive above 1000 m on Mt. Marau. These consist principally of different forms of *Partula otaheitana*, but also *Samoana burchi* (Kondo, 1973), a species believed extinct (Murray *et al.* 1988) but recently confirmed by molecular analysis (T. Lee, pers. comm.). Several populations of more than 30 individuals still survive in patches along the trail to Mt. Aorai, although individuals of *Euglandina rosea* are often seen at around 800 m altitude and also at 1200 m encroaching into partulid populations. No live partulids were found on the route to Mt. Mauru (where they were last seen in 2002) or from the Sentier de Milles Source to the summit of Mt. Pihaiateta (600 m to 1400 m), although they have since been seen on the latter trail (B. S. Holland, pers. comm.). In neither place did it appear that the populations had fallen victim to *E. rosea*. In contrast, along the trail from Pic Rouge to Masif du Pic Vert, there were live individuals of *E. rosea* and many empty shells of partulids. Above Plateau Taravao on Tahiti Iti, populations of partulids persist, even though *E. rosea* is also present.

DISCUSSION

The discovery in 1995 of apparently thriving populations of species of partulids previously believed extinct was a surprise (Murray *et al.* 1988). This led to a renewed search for endemic snails in 2001. Most of these searches took place at high altitudes (over 1000 m) where surveys and information from local biologists and mountain guides confirmed the presence of small isolated populations on the mountains Mauru, Tahiti, Aorai, and Atara and on the plateaus Faufiru and Terepo. The presence of the majority of endemic plant species at high altitude meant that these areas are regularly visited by botanists and good information was available. Because shells of *Euglandina rosea* but no live animals had been found among the partulid populations of Mt. Marau, it appeared that the predatory snail had reached the area but had not thrived there. This led to the suggestion that an altitudinal ceiling may exist for the principal agent involved in the extinction of Society Island partulids (Gerlach 1994). This did not, however, explain the abundant partulid populations remaining at sea level in the Te Pari district of Taiarapu Peninsula (Tahiti Iti). Whereas in 1995 there had been no evidence of the predator in this small arc of valleys in the extreme southeast, in the following years *E. rosea* spread quickly until by 2001 it had reached every valley.

An upgrade in the existing level of protective legislation has been proposed in order to safeguard the populations of partulids surviving above 1000 m altitude (Meyer *et al.* 2005) because the terrain would not be amenable to physical protection in the form of predator-proof protected area, a method being tested at lower elevations (Coote *et al.* 2004). However, if there were any surviving populations threatened by *Euglandina rosea* at low altitudes in the valleys of Tahiti, then measures such as reserves could be considered as realistic options. Because of the size and topographical nature of Tahiti, a systematic search of the valleys required a long time and extensive planning. Until the resources became available in 2003, these barely seemed to be viable options. Given the timescale of the contract, valleys on Tahiti Iti were unable to be included in the surveys.

It became clear after the first few discoveries of valley populations that only three species persisted and that all the others had most likely been extirpated. By far the most common species were the universally white *Partula hyalina* and the very similar *Partula clara*, which is polymorphic in shell color. The third species, *Samoana attenuata*, has a distribution and ecology that differs from most of the species in the genus *Partula*. It has always been a rare species, made elusive by the fact that it favors higher branches in the trees (Crampton 1916). It has also survived on the neighboring island of Moorea (Coote 1999). In the lowland forests of Tahiti it was represented in the current surveys by just a few individuals that were found occasionally.

No individuals of *Partula otaheitana* or *Partula affinis* (Pease, 1867) were found in any of the valleys of Tahiti Nui, yet in Crampton's 1906-09 collections *P. otaheitana* (of which at the time *P. affinis* was considered a subspecies) formed over 90% of all valley collections, except in the 7 valleys that had *Partula nodosa* (Pfeiffer, 1851) (Crampton 1916). *Partula nodosa* is now considered as extinct in the

wild, although it persists well in captivity (P. Pearce-Kelly, pers. comm.). In contrast, *Partula hyalina* and *Partula clara* together accounted for just over 5% of those same collections. Ratios of species similar to those reported by Crampton were found by researchers up until the introduction of *Euglandina rosea* in 1974 (J. B. Burch, pers. comm.). Emerging molecular evidence suggests that *P. hyalina* and *P. clara* should be synonymized (D. Ó Foighil, pers. comm.).

Tahiti Nui is divided ecologically into those valleys on the dry leeward side of the island, roughly between Mahina in the north and Pointe Maraa in the southwest, and the wet valleys that constitute the remainder. The flora is quite different in the two regions. Most noticeable is the distribution of the dominant alien plant pest species, *Miconia calvescens*, abundant in the eastern valleys but rarer in the drier western ones. In terms of partulid distribution, Crampton (1916) maintained that *Partula hyalina* occurred across the whole island, but preferred drier areas, and *Partula clara* was absent from the driest quadrant. However, there appeared little preference for any type of valley for either species, both being found in dry and wet, large and small. The densest and most widespread populations of both these species were, however, found in the small, wet valleys of the northeast.

Not enough is known about the ecology of the surviving species to determine why they should have escaped to some degree the ravages of *Euglandina rosea*, which has left extinct so many others across the Society Islands (Clarke *et al.* 1984, Murray *et al.* 1988, Cowie 1992). *Partula hyalina*, however, differs from the other species on Tahiti in that it is the only French Polynesian species of *Partula* that was not a single island endemic, occurring also on four of the Austral Islands and three of the Cook Islands (Crampton 1916). Because of this distribution, it was believed to be an ancient species (Crampton 1916), especially because it was universally white, in contrast to the conspicuous polymorphism of many other partulids in the Society Islands (Crampton 1916, 1932). However, recent genetic analysis confirms that some individuals of *P. hyalina* from the Austral Islands share mitochondrial haplotypes with those on Tahiti, suggesting evolutionarily recent among-archipelago dispersal (D. Ó Foighil, pers. comm.). *Partula hyalina* was generally the first species to be seen on entering valleys—in other words, it more easily tolerated disturbed (and drier) habitats (Crampton 1916). The finds during the current surveys confirm this ecological distribution.

As a result of these surveys the distribution of the remaining partulid species on Tahiti Nui can best be summarized thus: below 250 m altitude, *Partula hyalina*, *Partula clara*, and *Samoana attenuata*; between 250 m and 1000 m, none; above 1000 m, *Partula otaheitana* and *Samoana burchi*. *Partula affinis* seems to have disappeared from Tahiti Nui, but still survives on Tahiti Iti. *Partula nodosa* has been extirpated from the wild but is maintained in captivity. The two single-valley endemics, *Partula filosa* (Pfeiffer, 1851) and *Partula producta* (Pease, 1864), as well as two rare species of unclarified taxonomy, *Partula cytherea* (Crampton and Cooke, 1930) and *Samoana jackieburchi* (Kondo, 1981) are almost certainly extinct. The surviving populations of partulids in the valleys of Tahiti do not appear to be under any immediate threat apart from that of external forces acting on small population size, generally less than 50 individuals. A number of colonies are being regularly monitored for changes in their populations or their habitats.

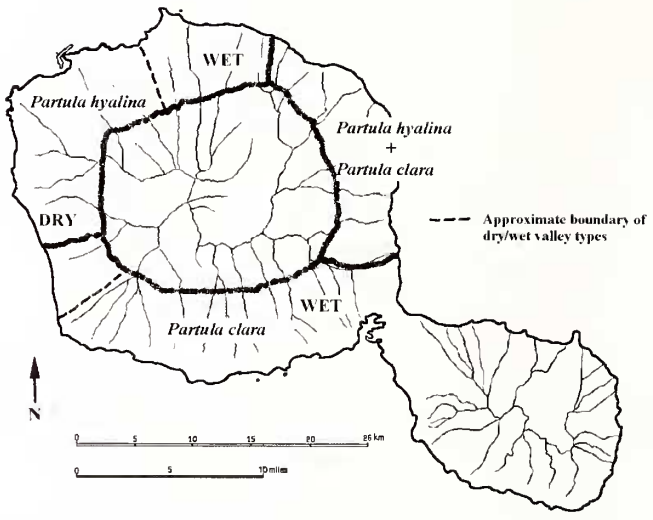

Figure 1. Current distributions of *Partula hyalina* and *Partula clara* on Tahiti.

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